Using 3D terrestrial laser scanning as data acquisition technique for the assessment of deviations in geometry between design and as-built models of large structures. A case study.

Greta Deruyter[1], Marc Hennau[2], Niek Dewulf[3], Vicky De Wolf[3]

[1]University College Ghent / Ghent University
greet.deruyter@hogent.be – greta.deruyter@ugent.be

[2]Couderé b.v.b.a.
marc.hennau@coudere.be

[3]University College Ghent

INTRODUCTION

3D models of the built environment can be obtained using different instruments and techniques such as total stations, GPS, photogrammetric applications and more recently terrestrial 3D laser scanning. (Grussenmeyer, Landes, Voegtle & Ringle, 2008) The latter is a fast method for acquiring 3D information and results in high density point clouds, with accuracies of a few millimetres. In most cases, several scans are combined to produce a comprehensive 3D model, which subsequently can be used to produce 2D drawings.

Up until now, most scanning applications are situated in the field of architecture, renovation, preservation of cultural heritage, archaeology, spatial planning, modelling of industrial installations and even the film industry.

Although there has been relatively little study of the opportunity to use this data acquisition technique for the comparison between design and as-built geometry of large structures, an accurate knowledge of the deviations is useful in the search for improved calculation, construction and assembly methods.

Therefore, in this paper, a case study is used to explore the possibility of using laser scanning in this context.This is done by following the whole process, from the planning phase over the data acquisition and generation of 2D drawings based on the point clouds, to the comparison of the as-built geometry and the interpretation of the resulting deviations.

CASE STUDY: BRIDGE ELEMENT AT LUMMEN (BELGIUM)

The Lummen (Belgium) motorway interchange connects the European motorways E313 and E314. To address safety and traffic congestion issues, all conflict situations will be resolved by reshaping the interchange. An innovative concept, in which new bridge elements are prefabricated alongside the existing infrastructure, makes it possible to move the elements into their final position in only one week-end, hence reducing hinder for the daily traffic. The company responsible for the realization is Jan De Nul NV.

Fig. 1: Motorway interchange – Lummen. Left: old situation with confliction traffic flows. Right: design visualisation. (source: www.klaverbladlummen.be, 2008)

Fig. 2: Construction site near E313 (source: Jan De Nul NV, 2008)

Fig. 3: Design visualisation: case study element (source: www.klaverbladlummen.be, 2008)

For the data acquisition two Trimble GX Advanced 3D scanners (Fig. 4 - left) were used. The scanners are operated by the Trimble® PointScape™ Software, installed on a Panasonic Toughbook CF-19 (Fig. 4 - right).

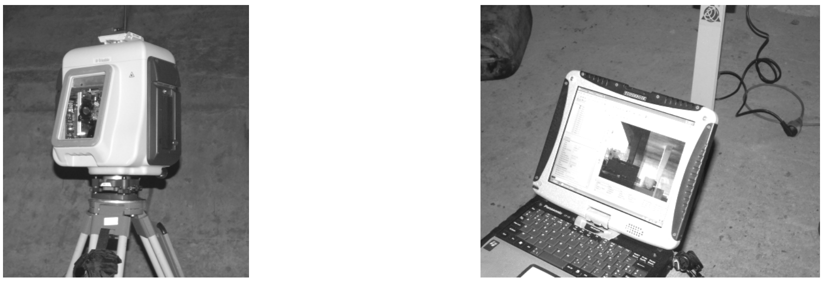

Fig. 4: Trimble GX Advanced controle (left) controlled by Trimble® PointScape™ Software on Panasonic Toughbook CF-19 (right)

To assure full coverage of both the inside and the outside of the bridge element ten scan positions and seventeen targets were used.

Before processing the data a completeness check has to be performed and data voids have to be detected and, if necessary, completed by additional scans. This was especially important in this case study because after assembly most parts of the bridge element are no longer accessible for scanning.

The Trimble® RealWorks Survey™ advanced version 6.2 was used to clean up, visualize, register, model and manipulate the data.

In order to compare the design with the as-built geometry, 2D drawings are generated from the point clouds using different tools provided by the software.

During the case study several geometry features are examined: the column dimensions, the implantation (placement) of columns, the dimensions of the side panels and the level of the bottom plate.

To be able to assess the results of the comparison between as-built and design, the tolerances values have to be known. They are given as a function of the dimensions of the different elements.

A consideration that has to be made is that exceeding the tolerance does not automatically means that construction errors were made, because the deviation between as-built and design is the result of construction parameters together with standard deviations of the scanning process (Tsakiri, Lichti & Pfeifer, 2006; Boehler, Bordas Vicent & Marbs, 2003).

CONCLUSIONS AND DISCUSSION

Deviations between the as-built situation and the design are inevitable. When using laser scanning as data acquisition technique to generate an as-built model, these deviations are the result of errors in construction together with uncertainties induced by the scanning procedure and the processing of the scan data.

The question to be answered is whether these deviations are acceptable in terms of, for instance, stability or esthetical considerations. Hence, the tolerance values are part of the constraints of the construction process.

Several methods can be used to determine the order of magnitude of the deviations and although for the case study the given geometrical constraints seem to be met, this cannot be stated with absolute certainty because of a number of shortcomings in the planning process of the scan survey of which the impact on the resulting deviations is uncertain.

When considering the use of laser scanning as data acquisition technique to investigate geometry and/or assembly variations of contruction elements - based on the experience gathered during the case study - following reflections and recommendations can be made:

- For every topographic survey the planning of the field campaign is an essential part that, to a large degree, contributes to the quality of the end result and to the efficiency of the whole data acquisition and post processing process. When using 3D laser scanning this is even more the case, especially when geometry issues are the main topic of the research.
- It is very important to determine the goals and objectives of the project and to have an insight in the requirements concerning the deliverables (2D, 3D, volume calculations,…), the level of detail and the desired accuracy. This knowledge is needed to

determine the correct scanning parameters such as resolution, distance, target configuration etc. and to be able to interpret the established deviations.

- When examining the geometry of construction parts it is imperative to attach targets to the part itself instead of in the surroundings, because the accuracy of the registration diminishes as the distance to the targets increases.
- To facilitate the comparison between as-built and design characteristic, points or edges can be marked. These characteristic elements can later be used to establish axis of symmetry of element parts, determine, adjust or synchronize the orientation of the as-built and design models, tie the design model to the as-built model etc.
- During the scanning one can be confronted with obstructions (scaffoldings, cables, construction waste, machinery, etc.) and time restrictions. Timely knowledge concerning such limitations is useful information for a better planning of possible laser scanner setup positions and target locations.
- If possible two types of scans should be considered in this kind of projects. The first scan should be used to determine construction flaws and should take place before assembly. A second scan after assembly can provide information concerning the correctness of - and deformations due to the assembly. Follow up scans can be performed to determine deformations under service load and deformations in time.

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